Group Learning Supported by a Simulation Model - An Experiment Design

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Abstract
This paper addresses the influence of information feedback on a decision process supported by a simulation model. A group of 118 graduate students participated in the experiment under four conditions: a_1) decision making with application of the simulation model with pretest, a_2) decision making with application of the simulation model and group information feedback with pretest, a_3) decision making with application of the simulation model without pretest, and a_4) decision making with application of the simulation model and group information feedback without pretest. The criteria function and number of simulation runs were observed. The hypothesis that decision-making using a simulation model and group feedback improve criteria function was confirmed. The model of learning during the decision process was developed.
Keywords: group decision, learning model, simulation, feedback, experiment design.

1 Introduction

Decisions generated in organizational systems are not dependent on the individual decision of a subject but rather on a group of experts working in a specific field. The group understands the considered system better and provides synergetic effects. Their interaction in the process of problem solving (decision-making), supported by advanced group support tools and interactive business simulators could make the individual and group analyses of the problem more efficient. Quality decisions can be made only if the decision group has the appropriate information. This assumes the group knows a model of a system, the criteria function and the state of nature. However, there are several problems in planning a laboratory experiment: reality in the design of the research, planning of the problem (organizational systems), framing of information, designing an effective and user-friendly interface. This paper addresses the influence of individual and group feedback information on the decision process supported by the application of a system dynamics model. Previous experiments considered the task of strategy determination with an explicitly defined criteria function (CF) under three experimental conditions: a_0) determination of strategy supported by a causal loop diagram (CLD), a_1) determination of strategy with application of a system dynamics (SD) model without group interaction, and a_2) determination of strategy with application of the SD model with subject interaction supported by group feedback information. The hypothesis that model application and group feedback information positively influence the convergence of the decision process and contribute to higher CF values was confirmed. However, the results suggested that the difference in frequency of simulation runs in the first eight minutes, where the two groups had the same conditions, might be caused by a phenomena of group belonging. This paper addresses the influence of feedback information on the group decision process supported by the application of the SD models. A Solomon experimental design was introduced in order to explore the cause of differences in simulation run frequency. The Solomon experiment design was conducted under four conditions: a_1) determination of the strategy with the application of the SD model without group interaction with pretest, a_2) determination of the strategy with the application of the SD model and group information feedback with pretest, a_3) determination of the strategy with application of the SD model without pretest, and a_4) determination of the strategy with application of SD model and group information feedback without pretest. A model of learning during the decision-making process was developed.

2 Business Simulator a Tool to Improve Learning Process

In order to improve method of learning of modeling and simulation, we built a business simulator aimed at presenting a more realistic decision process in enterprises. Students had to take an active part in the experiment and report about results. In this way, they were motivated to regularly attend and understand the lectures. However, if the participants are to be encouraged to experiment with a stimulator, the experiment has to be carefully prepared. The design of the experiment has to enable a controlled and creative environment; a business simulator has to reflect the real business situation and its functions in order to show the advantages of using the simulation model in decision support.

Figure 1 shows the simulation model used in the experiment developed using the SD method. The model described in Škraba et al. (2007) consists of: production, workforce and marketing segments, which are well known in literature (Hines 1996; Sterman 2000). In this model, the product price (r_1) positively influences income. However, as prices increase, demand decreases below the level it would otherwise have been. Therefore, the proper pricing that customers would accept can be determined. If marketing costs (r_3) increase, demand increases above what it would have been as a result of marketing campaigns. The production system must provide the proper inventory level to cover the demand, which is achieved with the proper determination of the desired inventory value (r_4). Surplus inventory creates unwanted costs due to warehousing; therefore, these costs have to be considered. The number of workers employed is dependent on production volume and workforce productivity, which is stimulated through salaries (r_2). Proper stimulation should provide reasonable productivity.

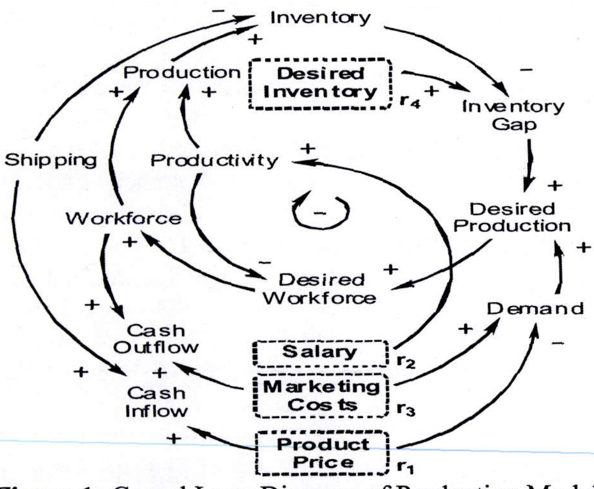

Figure 1: Causal Loop Diagram of Production Model.

Participants had the task of promoting a product, which had a one-year life cycle, on the market. They had to find the proper values of parameters r_i defined in the interval $r_{min} \leq r_i \leq r_{max}$. The model was prepared in the form of a business simulator (Škraba et al., 2007). The participants changed the parameter values via a user interface, which incorporated sliders and input fields for adjusting the values. After setting the parameters in the control panel, the simulation could be processed. Output was shown on graphs representing the dynamic response of the system and in the form of a table where numerical values could be observed. The CF was stated as the sum of several ratios, which were easily understood and known to the participants. It was determined that Capital Return Ratio (CRR) and Overall Effectiveness Ratio (OER) should be maximized at minimal Workforce and Inventory costs determined by a Workforce Effectiveness Ratio (WER) and Inventory / Income Ratio (IIR). The simulator enabled simultaneous observation of the system response for all variables stated by the criteria function during the experiment. A group of 147 subjects, senior university students, randomly scheduled in three groups participated in the experiment. The experiment was conducted under three experimental conditions:

a_0) Determination of strategy on the basis of a subjective judgment of the task. Participants had to make an individual judgment about the best possible strategy on the basis of the presentation of the model by the Causal Loop Diagram (CLD) and the stated CF. The participants had 30 minutes to determine the appropriate values of decision parameters and register their decisions in the paper form.

a_1) Individual decision-making supported by the simulation model. Participants were supported by the simulation model, which provided feedback information about the anticipated business outcome. There was no limitation on the number of simulation runs a particular participant executed on the simulation model within the experimental time. After each predetermined time interval (8+8+8+6 minutes) participants had to forward their selected business strategy to the network server and continue the search for the optimum business strategy.

a_2) Decision-making supported by both the simulation model and group feedback information. With this condition, the simulation model was connected to the group support system, which enabled the introduction of group feedback information into the decision process. Participants were able to examine the chosen business strategies (decision parameter values) of other participants in the decision group after the strategies were forwarded to the network server. Consequently, the participants could look into the group's "achievements" after the 8^{th}, 16^{th} and 24^{th} minute.

The results of the decision process gathered when group feedback information was introduced revealed that Group a_2 achieved higher criteria function values than in cases where the decision was based only on individual experience with a simulation model (Group a_1) and the lowest criteria function values were achieved on the basis of subjective judgment (Group a_0). The hypothesis that model application together with group feedback information positively influence the CF value was confirmed at $p = .01$ level.

These results were expected. However, we also expected that the results gathered after the first eight minutes would not differ for the groups working with the simulator (a_1 and a_2) for the same conditions that were in force in that time interval: individual use of the simulator. However, we found that the frequency of simulator use in the first eight minutes was significantly higher in Group a_2 than Group a_1. The experiment was repeated the following year with new participants at conditions a_1 and a_2 (Kljajić-Borštnar, 2003); the results were similar. The single factor ANOVA showed that there are highly significant differences of CF values between Groups a_1 and a_2 on a $p = .006$ level.

We also examined the dynamics of problem solving by observing the frequencies of simulation runs and the average value of CF achieved under the two conditions. The differences in the first eight minutes were significant again. In order to explain this occurrence, we conducted a new experiment according to a Solomon four-group experimental design.

3 Solomon Four-group Experimental Design

With the Solomon Four-group experimental design, we expected to estimate the effect of group belonging (as a result of the introduced group information feedback) and pretest effect (as a result of facilitation of the group decision process) on the decision-making.

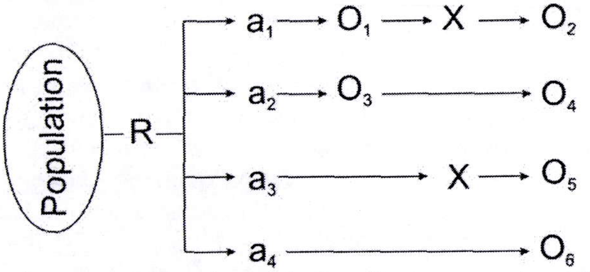

Figure 2: Solomon four-group experiment design; R means random, O_i means observed and X treatment.

Figure 2 shows a random assignment into four decision groups from the population of senior management students. The first two groups, a_1 and a_2, represent the pretest-post-test design (decision groups are facilitated and measured four times during the experiment, after the 8^{th}, 16^{th}, 24^{th}, and, finally, after the 30^{th} minute). The last two groups, a_3 and a_4, represent the post-test only design. All four groups were supported by the simulation model of a business system. One of each two groups (a_2 and a_4) had additional group information feedback at their disposal. Thus, we could assess whether the interaction between the pretest (in our case this also means facilitation of the group decision process) and the treatment (group information feedback) exists. At pretesting, the subjects were directed by a facilitator. They were told to submit their best chosen parameter values into the network database. After the submission, they continued with the search for the optimal combination of the parameter values. In contrast, the decision-making process of the two groups working without pretests was continuous, without facilitation. All measurements were automatic and group information feedback was available at all times. For this purpose, a new interface for data acquisition and proceeding has been developed.

A total of 118 senior graduate students from the University of Maribor participated in the experiment in order to meet the requirements of the syllabus. The students were randomly assigned to eight groups with 14 to 15 subjects, who were then assigned to work at one of the four experimental conditions: a_1, a_2, a_3, and a_4. The subjects who participated in the experiment became accustomed to the business management role facing the stated goal objective, which was in our case was presented in the form of CF. The presentation of the decision problem was prepared in the form of a uniform 11-minute video presentation, which differed only in the explanation of experimental condition at the end of each video presentation. The problem, the task and the business model were explained; the structure of the considered system was presented and the main parameters of the model were explained; the evaluation criteria for the business strategies were also considered. The work with the simulator was thoroughly explained in the video; a printed version of a problem description was provided for each subject as well. The participating subjects were familiar with SD simulators; therefore, working with the simulator was not a technical problem. Subjects were awarded by a bonus grade for their participation in the experiment. The experimental conditions were:

a_1) Individual decision-making process supported by a simulation model with testing after the 8^{th}, 16^{th}, 24^{th} and 30^{th} minute, assuming that each participant submitted the best-achieved set of parameter values $\{r_1, r_2, r_3, r_4\}$ to the network server at the end of each time interval; pretest-post-test design.

a_2) Decision-making process supported by simulation model and group information feedback with testing after the 8^{th}, 16^{th}, 24^{th}, and 30^{th} minute. Each participant submitted the best-achieved set of parameter r_i to the network server at the end of each time interval. Information about the best-achieved parameter values was fed back into the group support system. The participants got feedback on the defined strategies of all the participants in the group $R_i = \{r_1, r_2, r_3, r_4\}$; $i = 1, 2 \ldots n$; as well as the aggregated values in the form of parameter mean values. For example, if the considered parameter was Product Price and there were ten participants involved in the decision process, then all ten values for Product Price, recognized as the best by each participant, were mediated via feedback as well as the mean value of Product Price. The mean value provided the orientation for the parameter search and prevented information overload.

a_3) Individual decision-making process supported by a simulation model without a pretest (testing after 30^{th} min) assumed individual assessment of the decision-maker when determining the model parameters values $\{r_1, r_2, r_3, r_4\}$ by maximization of the CF using the SD model. At the end of the experiment, the subjects submitted the best-achieved parameter values to the network server; post-test design was used.

a_4) Decision-making process supported by a simulation model and continuous group information feedback (testing after the 30^{th} min). Each participant submitted the best-achieved set of parameter values $\{r_1, r_2, r_3, r_4\}$ to the network server at the end of experiment. However, information about the instantaneous optimization of the group was always at participants' disposal; post-test design was used.

4 Results of the Solomon Four-group Experiment

There was no significant difference of CF values between experimental groups. The reason for this probably lies in the small number of participants in comparison to the previous experiments. The Solomon experimental design requires four times more subjects then in the pretest-post-test design. However, the main goal of the Solomon four-group experiment design was to determine whether interaction between the pretest and the treatment exists. There is no single test that can be used on the data acquired by this experiment design (Campbell and Stanley, 1963); therefore, several statistical tests were chosen to determine the possible influence of pretests (facilitating) and treatment (group information feedback). Figure 3 shows values of CF achieved by the participants under experimental conditions where participants had to report their decisions four times during the experiment: a_1, a_2 at the end of each time interval. With Friedman's ANOVA test, it was confirmed that CF values increased during the experiment time (χ_{a1}=30.57, p_{a1} =.000; χ_{a2}=27.30, p_{a2} =.000); therefore it can be concluded that learning takes place during the decision-making process. Results show that the subjects' decisions did not differ after the first eight minutes when the same conditions were in place (Mann-Whitney test (U=415) at p=.762). After Group a_2 had received the group information feedback, they quickly approached the optimum CF value. The greatest increase in CF values was observed after the first time group information feedback was introduced (8th to 16th minute), confirmed by a Wilcoxon test (z=-2.995, p=.002). CF values significantly increased until the 24th minute (confirmed by a Wilcoxon test, z=-3.165, p=.001), but hardly changed towards the end of the experiment (in the last six minutes); confirmed by a Wilcoxon test (Z=-.660, p=.510). In contrast, the group without group information feedback (a_1) slowly continued to approach the optimal solution and significantly improved their results in the final phase of the experiment (after 24th minute). With a Wilcoxon test we confirmed that CF values significantly improved after each experimental phase (z_1=-2.584, p_1=.009; z_2=-2.259, p_2=.023; z_3=-2.869, p_3=.004).

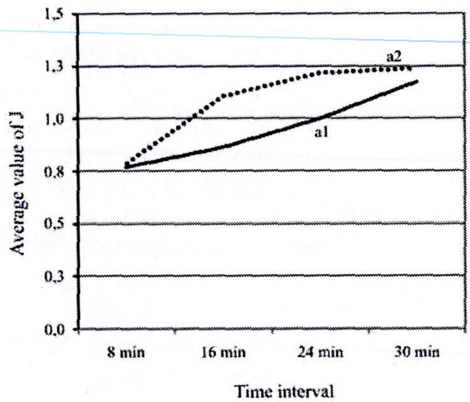

Figure 3: Average CF value at observed time intervals (8th, 16th, 24th and 30th minutes).

These results show that Group a_2 took six minutes less then Group a_1 to solve the decision-making problem. The results prove that learning occurs in the decision-making process supported by the simulation model.

4.1 Analysis of Feedback Seeking Behavior in Two Treatment Groups

In addition to recording every simulation run executed by a subject, we have also recorded every insight into group information feedback. This feedback was available to subjects at all times for the non-pretest group (a_4) from the beginning of the experiment, while the pretested group (a_2) had group information feedback introduced after each time they were required submit their decisions to the network database. With a Mann-Whitney test we have confirmed that the feedback seeking behavior of the pretest and non-pretest treatment groups differs significantly (U=202, p=.001). While Group a_2 had shown great interest in the group information feedback and almost constant interest in simulation runs, the interest of Group a_4 in group information feedback and simulation runs increased almost proportionally. In fact, the frequency of simulation runs of Group

a_2 is almost twice as high in comparison to Group a_4 at the beginning of the experiment and decreased after the 24th minute, while the subjects of Group a_4 continued to increase the frequency of simulation runs. This can be explained by 40% of subjects' of the Group a_2 who stopped performing simulation runs at the last experiment phase (after 24th minute). These were the subjects that have already approached the optimal solution. With a Spearman's ρ test, we confirmed that reasonably strong correlation exists between the frequency of simulation runs and CF values at experimental conditions a_1 ($\rho = .443$, $p = .014$), a_3 ($\rho = .432$, $p = .017$), and a_4 ($\rho = .500$, $p = .005$), but not at condition a_2 ($\rho = .231$, $p = .227$).

4.2 Interaction of Pretest and Treatment

Figure 4 shows frequency of simulation runs at pretest and post-test (8th and 30th minute) for all four experimental conditions. We can see that the frequency of Group a_2 (pretest treatment group) in the first eight minutes is slightly higher than the frequency of the pretested non-treatment Group a_1 and that both have higher frequencies than the two non-pretested groups (a_3 and a_4). Towards the end of experiment time, all groups show an equidistant increase of frequency, except the Group a_2 (pretest plus treatment). The groups' frequency of simulation runs is almost constant. From Figure 4, we can conclude that pretest (facilitation) and group information feedback influenced the number of simulation runs performed. With a two way ANOVA test we confirmed that treatment alone (group information feedback) does not influence the frequency of simulation runs ($F = .000$, $p = .9982$), pretest (facilitation of the decision process) influences frequency of simulation runs ($F = 6.895$, $p = .01$), and interaction between the pretest and treatment together influence the frequency of simulation runs ($F = 4.076$, $p = .046$).

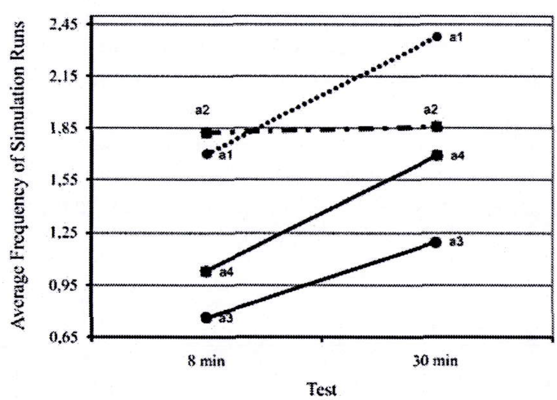

Figure 4: Solomon test for Frequency of simulation runs.

4.3 Learning Model of Decision Making Supported by Simulator

In order to explain the influence of individual information feedback (assured by a simulation model) and group information feedback (introduced by GSS) on the efficacy of problem solving, we have developed a CLD model of learning during the decision-making process. The model shown in Figure 5 was modified according to (Lizeo, 2005) and consists of three B and one R loops.

Loop B1 represents decision-making process supported by just a formal CLD model (in Figure 1), paper and pen (Škraba et al., 2003; Škraba et al., 2007). The decision maker solves the problem by understanding the problem and the task. The higher the gap between the goal and performance, the more effort one should put into understanding of the problem.

Loop B2 represents the decision-making supported by a simulation model and corresponds to experimental conditions a_1 and a_3 (groups supported by just individual feedback information of a simulation model). The higher the gap between the goal and performance, the higher is the frequency of simulation runs. The search for the optimal parameter values is based upon trial and error. The more simulation runs that the decision maker performs, the more he or she learns (on an individual level) and the smaller is the gap between performance and goal (in our case the optimized CF). The correlation between frequency of simulation runs and CF value was confirmed (p_{a1}=.014; p_{a3}=.017). We named this loop "Individual Learning Supported by Simulator".

Loop B3 represents direct contribution of group information feedback, while loop R suggests reinforcing effects of group influence on problem solving at Groups a_2 and a_4 (groups supported by individual feedback information of a simulation model and group information feedback provided by GSS). The decision maker of loop B3 understands the problem and the goal. He or she is supported by simulator and group information feedback. While the use of simulator supports the individual learning, the introduced group information feedback enhances the group performance. Consequently, the increased group performance reduces the need to experiment on the simulator. In other words, the decision maker supported by group information feedback has a broader view of the problem, an insight into new ideas and needs to put less effort in problem solving. In contrast, the group information feedback stimulates group members to actively participate in problem solving so that they perform more simulation runs in the process of searching for the solution (Kljajić-Borštnar, 2006). When the group is satisfied with its performance, the frequency of simulation runs decreases.

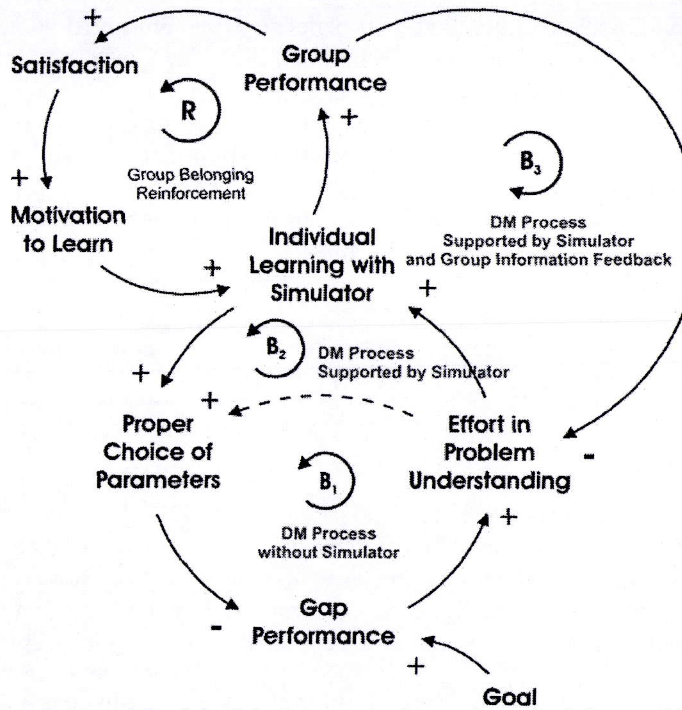

Figure 5: Learning model of decision group under various decision-making conditions.

Loop R can be further explained by interaction between group information feedback and facilitation of the decision-making process. As we have observed in (Kljajić Borštnar, 2006) the group information feedback together with facilitation contributes to higher feedback seeking behavior and a higher commitment to problem solving. Facilitation in this case serves as motivation and orientation towards the goal. Subjects of Group a_2 had to make their decisions three times during the experiment before they submitted their final decisions, while their colleagues in Group a_4 were left to their own pace and had to make their final decision at the end of the experiment. Participant's opinions about participation in the experiment were solicited by questionnaires, which were filled in via the web application. Questions were posed in the form of a statement and agreement with the statement was measured on a 7-point Likert type scale, where 1 represents very weak agreement, 4 a neutral opinion, and 7 perfect agreement with the statement. There were 10 basic questions about the experiment. The average answer to the statements in the opinion questionnaire was high: between 5 and 6. We performed an ANOVA test to explore the differences in opinions among the four experimental conditions. It showed high agreement in opinion between groups as well. From the opinions expressed via the questionnaires, we can extract some general observations:

1) 99% of the participants agreed on the general quality of the experiment,
2) 83% of the participants agreed that the decision problem was correctly presented,

3) 68% of the participants agreed that they understood the presented decision problem,
4) 93% of the participants agreed that the simulator was easy to use,
5) 84% of the participants agreed that the use of simulator contributed to understanding of the problem,
6) 70% of the participants agreed that there was enough time for decision making,
7) 63% of the participants agreed that they were motivated to solve the problem,
8) 88% of the participants agreed that they benefit from participating in the experiment,
9) 97% of the participants agreed that experiment was well organized,
10) 92% of the participants agreed that use of the simulator contributed to better decision-making.
We can say that in general students were satisfied with the experiment as a method of teaching and the use of simulation in decision support.

5 Conclusions

In prior experiments (Škraba et al., 2003; Škraba et al., 2007) we have proved the positive impact of individual information feedback assured by a simulation model and group feedback information on the decision-making process. However, the results suggested that differences in the frequency of simulation runs in the first eight minutes of the experiment, where two simulation groups had same conditions, might be caused by the phenomena of group belonging. Hence, the new experiment was introduced, a pseudo Solomon experimental design, and the following experimental conditions were formulated: a_1) individual decision-making process supported by a simulation model with testing after the 8^{th}, 16^{th}, 24^{th} and 30^{th} minute, a_2) decision-making process supported by a simulation model and group information feedback with the testing after the 8^{th}, 16^{th}, 24^{th} and 30^{th} minute, a_3) individual decision-making process supported by a a simulation model with testing after the 30^{th} minute, and a_4) decision-making process supported by a simulation model and continuous group information feedback with testing after the 30^{th} minute. The experiment was performed on the business simulation model in order to clarify the usefulness of simulation in solving management problems and to acquire knowledge about the learning taking place in a group decision process supported by the SD model. The criteria function was explicitly defined in order to increase the level of experimental control.

We confirmed the hypothesis that application of the individual information feedback assured by the simulation model positively influences the learning process of an individual decision. We also confirmed that additional application of the group feedback information contributes to a higher convergence and group unity. On the basis of our analysis, we can conclude that the group information feedback introduced into the decision-making process contributes to higher convergence of the decisions group and aids in faster decision problem solving (six minutes). Furthermore, we confirmed that interaction of treatment (group information feedback) and testing effects (facilitation) affects the dynamics of the decision-making process (frequency of simulation runs at $p=.046$). Thus, we showed how group feedback and the facilitator are extremely important during complex problem solving. Based on these results, we developed a

CLD model of learning during the decision-making process supported by a simulation model. In the participants' opinion, the application of the simulation model contributes to a greater understanding of the decision problem, to faster solution finding and greater confidence of the participants. The participants agreed that the clear presentation of the problem motivates them to finding the solution.

Acknowledgements

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